OCCUPATIONAL EXPOSURE TO NITROGEN DIOXIDE
A Partial Review of the Literature

Marc Rumminger, Ph.D.
Senior Engineer
Cleaire Advanced Emission Controls
San Leandro, CA

NO_2 Exposure Limits

Legal exposure limits are set by Congress and are enforced by the Occupational Safety and Health Administration (OSHA). The OSHA permissible exposure limit (PEL) is 5 ppm (Note: a glossary is at the end of this document) and is an 8 hour time-weighted average. It is also a ceiling limit "which shall not be exceeded during any part of the work day" [1]. The NIOSH *recommended* exposure limit is a 1 ppm average over a 15 minute period [2]. The American Conference of Governmental Industrial Hygienists (ACGIH) sets recommended limits for exposure and call their limits the "threshold limit value". In their words, "Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects" [3]. The TLV for NO_2 is 3 ppm time-weighted over 8 hours, and 5 ppm over a 15 minute period [3].

Review of Occupational Exposure Studies

Despite the use of thousands of NO_2-making DPFs on trucks and buses in Europe and millions of NO_2-making DOCs on diesel passenger cars in Europe, very few research articles in the scientific literature about occupational exposure to NO_2 from diesel engines equipped with catalytic devices could be found[*]. Reports about ambient NO_2 concentration and occupational exposure to diesel particulate matter (without simultaneous measurement of NO_2) are numerous, but are not considered in this document.

Many studies have been conducted to assess occupational exposure to NO_2 while working near a diesel engine, including electric utility work [4], in bus garages [5-8], in freight distribution centers [9], tunnels [10], and in airports [11]. Only one of the studies, however, investigated the effect of DPFs on worker exposure.

Ulfvarson et al. [10] studied the pulmonary function of tunnel workers exposed to diesel exhaust during normal work activity. They examined the effect of two control devices: catalyzed DPFs and dust respirators. Fifteen workers (drivers and "rock workers") were tested after working with 1) uncontrolled diesel equipment, 2) diesel equipment retrofitted with catalyzed DPFs, and 3) personal dust respirators. They found that the catalytic exhaust filters had a protective effect on pulmonary function, most notably on the truck drivers.

[*] My searches were limited to scientific journals, handbooks, and U.S. government agencies (e.g., NIOSH, OSHA). I also performed a brief but unsuccessful on-line search of the European Union websites. Additional searches should be performed to determine if the EU or the member countries have sponsored studies on this subject.

Unfortunately, the article lacks detailed documentation on the catalyzed DPFs, and it is not definitively stated whether they were coated with an NO_2-making precious metal or a NO_2-neutral base metal†. Nonetheless, the paper demonstrates the pulmonary benefits of removing diesel particulate from the occupational environment.

A study conducted by the IVL Swedish Environmental Research Institute involved measurements of NO_2 for two likely exposure conditions [12]. The first was a drive-by, in which a CRT-equipped truck passed the sampling zone at a fixed speed after several warm-up laps. The speed of the warm-up was chosen to heat the catalyst to the temperature of maximum NO_2 formation. The second was a bus stop, with a CRT-equipped truck driving a conditioning lap to heat the catalysts and then stopping near the measurement equipment for 45 seconds before driving away. In both tests, the maximum NO_2 levels occurred near the tailpipe (which was 1 meter above ground) with the concentration dropping rapidly over time and space. For example, on the truck stop simulation, at a point 1 m from the tailpipe, the NO_2 concentration was 3.9 ppm over a 1 second averaging time, but just 0.56 ppm when averaged for 2 minutes. Fifteen meters away from the tailpipe, the 1 second average was 1 ppm, and the 2 minute average was 0.04 ppm. *At no point and for no averaging interval did the measured NO_2 exceed the OSHA ceiling of 5 ppm.* The study's conclusion was that "measured NO_2 levels, when averaged over the prescribed one hour period, are substantially below the European NO_2 guideline level of 200 $\mu g/m^3$ [0.11 ppm]."

Whittaker et al. [4] used personal samplers to measure exposure of utility workers to several pollutants of interest, notably NO_2 and carbonaceous material. Eight operating headquarters in Georgia were examined. The operating HQs serve as fleet depots, supply warehouses, truck maintenance centers, and as work coordination centers. Area monitoring of particulate and gaseous pollutants was conducted in the truck bays at each site. In addition, linemen and winch truck operators (WTOs) wore personal samplers for a period of 2 days in the summer and 2 days in the winter to obtain information about pollutants in their personal breathing zone. Background sampling was performed by collecting particulate matter and gas samples for 3 to 4 hours at a job site that had been worked the *previous day* (so there was no utility truck running). The background thus represents a rough estimate of the emissions not assignable to the utility truck(s). The NO_2 results of the study are shown in Table 1. Also shown is a rough approximation of the "engine contribution," which is defined here as the difference between the measured concentration (personal breathing zone sample collected during entire work day) and the background concentration (area samples measured only at the worksites).

Both the time weighted average (TWA) and short term exposure limits (STEL) were significantly higher in the truck bay than for the linemen and WTOs. The authors note that the truck bay was poorly ventilated and provide that as a possible reason for the higher levels. Although not shown in the results table, the authors also found that STELs for the truck bay and lineman in the winter were significantly higher.

---

† The article states that "The exhaust pipe filters were a ceramic type from Emissionsteknik AB, with a catalytic surface layer to decrease the ignition temperature of the arrested 'soot' particles to about 400 °C. According to the specification of the manufacturer, the particle emission will be decreased by 85% by use of the filter. No oxidation catalyst for gaseous components of the diesel exhaust was used in this investigation."

Table 1: NO_2 exposure results for eight electric utility operating headquarters (from [4]). The "#>DL" row is the number of samples that were above the NO_2 detection limit of approximately 0.1 ppm.

	NO_2 time weighted average (ppm)	NO_2 Short-term exposure limit (ppm)	Approximate engine contribution (time weighted average)
Background*			
Number of Samples	5	5	
# > Detection Limit	2	3	
Mean**	0.2	0.4	-
Standard Deviation	0.1	0.3	
Truck bay***			
Number of Samples	13	13	
# > Detection Limit	11	11	
Mean	0.8	1.2	0.8
Standard Deviation	0.8	1.9	
Lineman†			
Number of Samples	19	18	
# > Detection Limit	10	16	
Mean	0.3	0.5	0.1
Standard Deviation	0.2	0.3	
WTO†			
Number of Samples	5	5	
# > Detection Limit	5	4	
Mean	0.4	0.8	0.4
Standard Deviation	0.2	0.6	

* Area samples at various work sites on the day following worker sampling
** All means are geometric means
*** Area samples
† Personal breathing zone samples

An ARB-funded project performed by researchers from UCLA and UC Riverside included measurements of pollutant concentrations (including NO_2) inside and outside of six school buses (two relatively old diesel, two relatively new diesel, a relatively new diesel bus with CRT, and a CNG-fueled bus) [13]. The concentrations inside the bus were most significantly affected by three factors: "self-pollution" by the bus's own exhaust, pollutant emission by other vehicles, and the background concentration of pollutants. In general, NO_2 concentrations were higher inside the bus than outside the bus. NO_2 concentrations for the six buses were compared and discussed, but since the study was not designed to compare performance of different buses, the authors stated that broad conclusions about the effect of bus design on in-cabin pollutant concentration are not appropriate.

A NIOSH study for Kalamazoo Transit was performed at a 61,000 ft^2 garage that houses 40 diesel buses [5]. It involved short term (15 minute) and full-shift (~8 hour) personal sampling of two bus drivers in the garage area performing the normal bus start-up procedures. Although most NO_2 concentrations were low, the authors report that one of the short-term NO_2 exposures was 4.6 ppm. Several recommendations are made, including an evaluation of the garage ventilation system and changing from ground-level tailpipe openings to top-of-bus tailpipe openings. The tailpipe change would remove a significant amount of exhaust from the workers' breathing zones.

A NIOSH study for San Francisco Municipal Railway was performed at the Flynn facility [6], which is a single large building that houses approximately 120 diesel buses. All NO_2 samples were "general area" samples, and therefore the results cannot be directly compared with general exposure criteria. However, the area-sample results suggest the potential of NO_2 short-term exposures exceeding a level of 1 ppm. The authors concluded that "Based on both visual observations of air flow and the analysis of particle concentration data, the ventilation was determined to be inadequate for the amount of diesel exhaust generated. The diesel exhaust, which accumulated in the bus staging and service areas during peak periods of operation, was not adequately removed and replaced with outside air." Two of the four recommendations made to the facility operators were to improve ventilation.

Other NIOSH studies (Houston Hobby Airport, Costa Mesa Fire Department, and Yellow Freight) have not found significant levels of NO_2 in the diesel workplace [9, 11, 14].

In the late 1980s, Ulfvarson and co-workers [8] used personal sampling and area sampling to measure NO_2 exposures to 17 bus garage workers. They found time-weighted average exposures of 0.1 – 0.59 ppm (0.2-1.1 $\mu g/m^3$).

Also in the late 1980s, Gamble and others [7] collected samples of NO_2 and respirable particulate matter using personal samplers on 232 workers in four garages. They found a mean time-weighted concentration of 0.23 ppm of NO_2 (with standard deviation of 0.24, range of 0.13 to 0.56).

Glossary

Ceiling Limit - The maximum concentration of a material in air that must never be exceeded, even for an instant. [15]

Permissible Exposure Limit (PEL) - The maximum occupational exposure permitted under the OSHA regulations. [16]

Recommended Exposure Limit (REL) - This abbreviation usually refers to a recommendation formally made by NIOSH and published in a Criteria Document for a particular agent or category of agents. [16]

Short-Term Exposure Limit (STEL) - A term used by ACGIH to indicate the maximum average concentration allowed for a continuous 15 minute exposure period. [15]

Threshold Limit Value (TLV) - An occupational exposure value recommended by ACGIH to which it is believed nearly all workers can be exposed day after day for a working lifetime without ill effect. [3]

Time Weighted Average (TWA) - The average concentration of a chemical in air over the total exposure time - usually an 8-hour work day. [15]

References

1. 29 Code of Federal Regulations, Part 1910.1000, "TABLE Z-1 Limits for Air Contaminants".

2. NIOSH, "Criteria for a Recommended Standard for Occupational Exposure to Oxides of Nitrogen," HEW Publication Number 76-149, Department of Health, Education, and Welfare, 1976.
3. American Conference of Governmental Industrial Hygienists. *2001 TLVs and BEIs*, American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 2001.
4. Whittaker, L. S., MacIntosh, D. L., and Williams, P. L., "Employee Exposure to Diesel Exhaust in the Electric Utility Industry," *American Industrial Hygiene Association Journal* **60:** 635-640, 1999.
5. Cook, C. K., "Health Hazard Evaluation for Metro Transit, Kalamazoo, Michigan," HETA 93-0633-2455, available on-line at www.cdc.gov/niosh/hhe/, National Institute for Occupational Safety and Health, 1994.
6. Blade, L. M. and Mortimer, V. D., "Health Hazard Evaluation for San Francisco Municipal Railway, Flynn Facility," HETA 98-0041-2741, available on-line at www.cdc.gov/niosh/hhe/, National Institute for Occupational Safety and Health, 1999.
7. Gamble, J. , Jones, W., and Minshall, S., "Epidemiological-Environmental Study of Diesel Bus Garage Workers: Acute Effects of NO_2 and Respirable Particulate on the Respiratory System," *Environmental Research* **42:** 201-214, 1987.
8. Ulfvarson, U., Alexandersson, R, Aringer, L, Svensson, E, Hedenstierna, G, Hogstedt, C, Holmberg, B, Rosen, G, and Sors, M, "Effects of Exposure to Vehicle Exhaust on Health," *Scandinavian Journal of Work, Environment and Health* **13:** 505-512, 1987.
9. Zaebst, D. D., Stern, F. B., Cooper, T. C., and Heitbrink, W. A., "Health Hazard Evaluation for Yellow Freight," HETA 90-088-2110, available on-line at www.cdc.gov/niosh/hhe/, National Institute for Occupational Safety and Health, 1990.
10. Ulfvarson, U., Alexandersson, R., Dahlqvist, M., Ekholm, U., and Bergstrom, B., "Pulmonary Function in Workers Exposed to Diesel Exhausts: the Effect of Control Measures," *American Journal of Industrial Medicine* **19:** 283-289, 1991.
11. Decker, J. and Donovan, B., "Health Hazard Evaluation for Southwest Airlines Houston Hobby Airport," HETA 1993-0816-2371, available on-line at www.cdc.gov/niosh/hhe/, National Institute for Occupational Safety and Health, 1994.
12. Allansson, R., Tancell, P., Walker, A. P., and Warren, J. P., "NO_2 Emissions from a CRT Filter-Equipped Truck in Simulated Public Environments," Johnson Matthey Autocatalyst Technology Centre and the Swedish Environmental Research Institute (IVL), 1999 .
13. Fitz, D. R., Winer, A. M., Colome, S., and others, "Characterizing The Range Of Children's Pollutant Exposure During School Bus Commutes," Contract No. 00-322, available on-line at www.arb.ca.gov/research/schoolbus/schoolbus.htm, California Air Resources Board, 2003.
14. Roegner, K. C., Sieber, W. K., and Echt, A., "Health Hazard Evaluation for Costa Mesa Fire Department, Costa Mesa, California," HETA 99-0266-2850, available on-line at www.cdc.gov/niosh/hhe/, National Institute for Occupational Safety and Health, 2001.
15. Hazard Evaluation System and Information Service, California Occupational Health Branch, Glossary, http://www.dhs.ca.gov/ohb/HESIS/utsgloss.htm, accessed on May 19, 2004.
16. American Conference of Governmental Industrial Hygienists, Acronyms, http://www.acgih.org/Resources/acronyms.htm, accessed on May 19, 2004.